PETROLOGY OF ANOMALOUS MAFIC ACHONDRITE POLYMICT BRECCIA PASAMONTE. D. W. Mittlefehldt[1], E. L. Berger[2], and L. Le[2], [1]Astromaterials Research Office, NASA Johnson Space Center, Houston, TX, USA (david.w.mittlefehldt@nasa.gov), [2]GCS-Jacobs JETS-NASA Johnson Space Center, Houston, TX, USA.

Introduction: The most common asteroidal igneous meteorites are eucrite-type basalts and gabbros – rocks composed of ferroan pigeonite and augite, calcic plagioclase, silica, ilmenite, troilite, Ca-phosphate, chromite and Fe-metal [1]. These rocks are thought to have formed on a single asteroid, widely considered to be 4 Vesta, along with howardites and diogenites [1, 2]. High precision O-isotopic analyses have shown that some eucrites have small, well-resolved O-isotopic differences from the group mean [3-5]. These O-anomalous eucrites are thought to hail from asteroidal parents that are distinct from that of eucrites [5].

Three O-anomalous eucrites are PCA 82502, PCA 91007 (paired) and Pasamonte, all of which have the same O-isotopic composition [5, 6]. Our petrologic studies have shown that PCA 82502 and PCA 91007 have well-resolved anomalies in low-Ca pyroxene Fe/Mn compared to eucrites [6]. Divalent Mn and Fe are homologous species that do not greatly fractionate during igneous processes; mafic mineral Fe/Mn can be used to fingerprint parent object sources [7]. Previous petrological studies of Pasamonte [8-10] have not yielded sufficiently precise Fe/Mn ratios to allow distinction of anomalies of the scale of those found for the PCA basalts. We have begun petrological study of Pasamonte for comparison with our results on normal and anomalous eucrites [6], and to constrain its origin.

Petrology: PCA 82502 and PCA 91007 are monomict breccias of fine-grained, vesicular basalt [6]. Pyroxenes in these rocks have been homogenized in Fe/Mg and correspond to Type 4 [11]. Pasamonte contains unequilibrated pyroxenes of Type 2 [12]. However, the Pasamonte clast suite includes unequilibrated basalts with zoned pyroxenes and granulitic breccias with equilibrated pyroxenes [8, 9]. It lacks diogenitic pyroxene clasts; it is a polymict basaltic breccia [8, 9].

We have studied two serial thin sections of Pasamonte, USNM 897-12 and 897-13, which show that it is a clast-rich basaltic breccia. Two main types of mafic clast are present: (i) very-fine- to fine-grained, variolitic to subophitic to ophitic basalts with pyroxenes zoned from Mg-pigeonite to Fe-augite (Fig. 1a), and (ii) fine- to medium-grained hypidiomorphic-granular to allotriomorphic-granular microgabbros containing exsolved pyroxenes with augite lamellae in pigeonite hosts and homogeneous Fe/Mg (Fig. 1b). Some of the basaltic clasts are rich in mesostasis containing silica and fine-grained ferroan olivine. Some mesostasis regions include symplectic intergowths of olivine+augite+silica+pigeonite+ilmenite. Microgabbros include medium-grained silica, but ferroan olivine is rare, perhaps only due to the inherent non-representativeness of small, medium-grained clasts. Many clasts show variations in grain size and some in texture. Other clast types include possible impact-melt clasts and mafic breccia clasts. Mineral fragments in the matrix include pyroxene, plagioclase, silica, ferroan olivine and oxides that are coarser than any observed in mafic clasts (cf., [9]). Mg-pigeonite grain fragments in the matrix (green in Fig. 1) have ferroan rims formed by post-brecciation metasomatism [13].

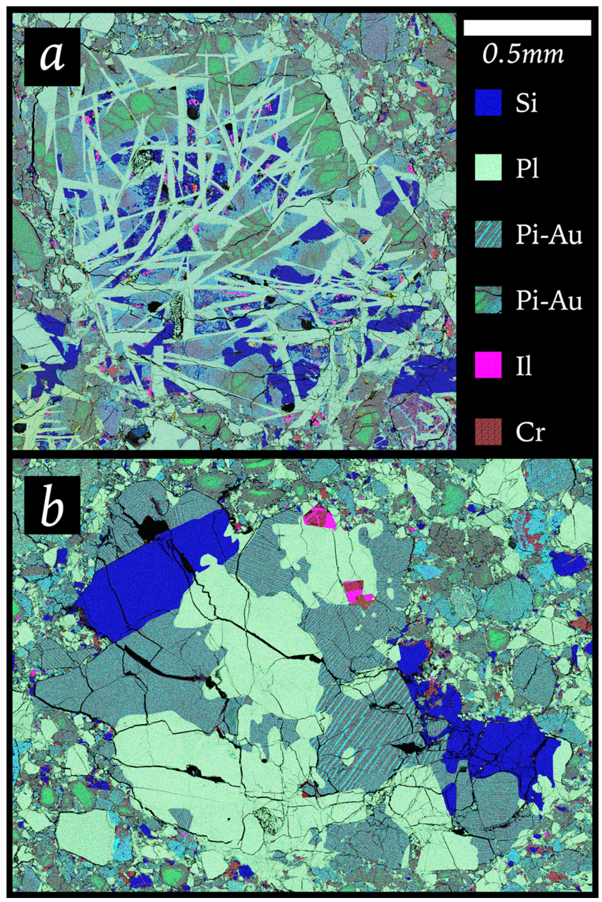

Figure 1. a. Unequilibrated subophitic basalt clast 13-3. b. Equilibrated hypidiomorphic-granular microgabbro clast 12-6.

Pyroxene analyses of equilibrated microgabbro clasts vary in Ca-Mg-Fe along tie-lines between low-Ca and high-Ca pyroxenes, as is typical of metamorphosed basaltic eucrites [12] (Fig. 2a). The least ferroan equilibrated clasts have compositions straddling

the tie line between orthopyroxene and augite compositions from Sioux County basaltic clasts; others are more ferroan. One of the equilibrated clasts, 13-8, appears to contain pyroxenes of uniform Ca-Mg-Fe (Fig. 2a), but this might be an artifact of their being few pyroxenes to analyze in this clast. Individual unequilibrated clasts, e.g. 13-3, can have pyroxene compositions that span the entire range of the clast suite.

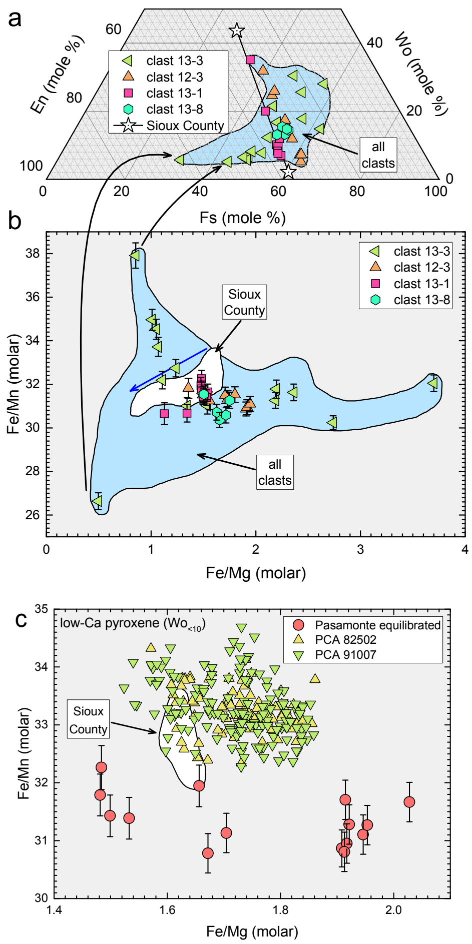

Figure 2. a. Pyroxene quadrilateral for representative Pasamonte clasts, and Sioux County basaltic clast end member pyroxenes. b. Fe/Mn vs. Fe/Mg for clasts compared to field for Sioux County basaltic clasts; blue arrow – low-Ca to high-Ca pyroxenes for Sioux County. c. Fe/Mn vs. Fe/Mg for equilibrated clasts compared to paired PCA basalts and field for Sioux County basaltic clasts. Uncertainty bars: 2σ standard deviations for individual analyses. PCA 82505, PCA 91007 and Sioux County data from [6].

Pyroxene Fe/Mn for the equilibrated clasts have a relatively narrow range, 30.2-32.4 (Fig. 2b). In contrast, unequilibrated clast 13-3 has a wide range – 26.6 to 37.9; the extremes are for the two most magnesian pyroxene analyses. A wide range in pyroxene Fe/Mn is characteristic of unequilibrated clasts. Comparing low-Ca pyroxenes ($Wo_{<10}$) for the equilibrated clasts with those of anomalous basalts PCA 82502 and PCA 91007 show that Pasamonte pyroxenes have a significantly lower Fe/Mn than those of the latter (Fig. 2c).

Discussion: As noted [8, 9], Pasamonte contains a variety of lithic clasts. The majority of them are either finer-grained basaltic clasts containing unequilibrated pyroxenes, or coarser-grained microgabbros containing equilibrated pyroxenes. Pyroxene equilibration among eucrites is thought to have been caused by global crustal metamorphism [11]. If the same is true for the Pasamonte parent asteroid, then the assemblage of unequilibrated and equilibrated clasts implies impact mixing of different geological terrains (polymict breccia), rather than from texturally distinct portions of a large basalt flow (monomict breccia).

The Fe/Mn of low-Ca pyroxenes in equilibrated Pasamonte clasts are significantly lower than those of the PCA pair with which Pasamonte shares an O-isotopic composition [5, 6], but the Fe/Mg of pyroxenes from the three meteorites overlap (Fig. 2c). Thus, the Fe/Mn difference cannot be ascribed to igneous fractionation. This difference could indicate separate parent asteroids for Pasamonte and the PCA pair. Pasamonte low-Ca pyroxenes have significantly lower Fe/Mn than Sioux County, which we have previously shown is well-resolved in Fe/Mn from the PCA pair [6]. Thus, Pasamonte has petrological and O-isotopic [3-5] differences from normal basaltic eucrites. Further work will focus on detailed petrological comparisons with the PCA pair and normal eucrites.

Key Findings: Mafic clasts in Pasamonte sampled at least two distinct geological terrains. Pasamonte is petrologically distinct from paired basalts PCA 82502 and PCA 91007. Although Pasamonte shares an O-isotopic signature with the latter two, it might have been derived from a different parent asteroid.

References: [1] Mittlefehldt D. W. (2015) *Chem. Erde Geochem., 75,* 155. [2] McSween H. Y. Jr. et al. (2013) *Meteoritics & Planet. Sci., 48,* 2090. [3] Wiechert U. H. et al. (2004) *Earth Planet. Sci. Lett., 221,* 373. [4] Greenwood R. C. et al. (2005) *Nature, 435,* 916. [5] Scott E. R. D. et al. (2009) *Geochim. Cosmochim. Acta, 73,* 5835. [6] Mittlefehldt D. W. et al. (2016) *LPS XLVII,* Abstract #1240. [7] Papike J. J. et al. (2003) *Am. Min., 8,* 469. [8] Metzler K. et al. (1994) *LPS XXV,* Abstract #1451. [9] Metzler K. et al. (1995) *Planet. Space Sci., 43,* 499. [10] Lentz R. C. F. et al. (2007) *LPS XXXVIII,* Abstract #1968. [11] Yamaguchi A. et al. (1996) *Icarus 124,* 97. [12] Takeda H. & Graham A. L. (1991) *Meteoritics, 26,* 129. [13] Schwartz J. M. & McCallum I. S. (2005) *Am. Min., 90,* 1871.